Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

SHOUT
SHARE
IT

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 145

Contribution from the Forest Service, Henry S. Graves, Forester.
April 12, 1915.

PROFESSIONAL PAPER.

TESTS OF WOOD PRESERVATIVES.

By HOWARD F. WEISS, *Director*, and C. H. TEESDALE, *In Charge of Wood Preservation, Forest Products Laboratory, Madison, Wis.*

INTRODUCTION.

A list of the various substances that have been used or suggested for preserving timber from decay would include a surprisingly large number of those known to industrial chemistry. By-products for which no use could be found have often taken their last stand as possible preservatives of wood. There have been sent to the Forest Products Laboratory for test the condensed fumes of smelters, the waste liquors of pulp plants, the refuse of tanneries, the skimmed milk of creameries, and miscellaneous assortments of compounds under trade names. Many of these have not been tested, because the claims made for them were manifestly impracticable. Those, however, which showed some promise or about which numerous inquiries were received were admitted to test.

The object of the tests, which were carried on at the Forest Products Laboratory maintained in cooperation with the University of Wisconsin, was to secure data on the practical value of these compounds and chemicals as wood preservatives. More than this, however, it was thought that such an investigation would show clearly

[1] The following members of the Forest Products Laboratory performed the experiments herein described: Ernest Bateman, chemist in forest products; C. J. Humphrey, pathologist, Bureau of Plant Industry; Ruth Fleming, scientific assistant, Bureau of Plant Industry; Robert E. Prince, assistant engineer in forest products.

Acknowledgment is also made to Ira H. Woolson, consulting engineer, the National Board of Fire Underwriters, for valuable assistance in the inflammability tests, and to the following cooperators, who furnished some of the preservatives used: United Gas Improvement Co., Philadelphia, Pa.; Bruno-Grosch & Co., New York City; Carbolineum Wood Preserving Co., Milwaukee, Wis.; C. A. Wood Preserver Co., St. Louis, Mo.; Marden, Orth & Hastings, Boston, Mass.; Logged-Off Land Utilization Co., Seattle, Wash.; Lake Superior Iron & Chemical Co., Detroit, Mich.; Spirittine Chemical Co., Wilmington, N. C.; Materials Preserving Co., Burlington, Vt.; Atlantic Turpentine & Refining Co., Savannah, Ga.; Indian Refining Co., New York City; Copper Oil Products Co., New York City; Balaklalla Consolidated Copper Co., Coram, Cal.; Franz Workman, Scotland (representing Messrs. Bruening & Marmetschke); John M. Long, Winston, Va.; Philadelphia Quartz Co., Chester, Pa.; Blagden, Waugh & Co., London, England.

the deficiencies of present practice in wood preservation and pave the way for increasing its efficiency by suggesting lines for orginal research.

From 40 to 90 per cent, or an average of over 60 per cent of the total cost of treating wood, is chargeable to the preservative alone. In ordinary treatments with coal-tar creosote it is common practice to inject 5 to 10 pounds of the oil per cubic foot of wood, although toxicity tests indicate that about one-half of a pound will prevent fungous growth; in other words, exclusive of subsequent changes, from 10 to 20 times as much creosote is used per volume of wood as is theoretically required. The possibility of safely reducing this amount, and consequently the cost of treatment, is one of the problems referred to. The tests described herein should therefore be considered simply as preliminary to the more difficult problems involved.

PROPERTIES INVESTIGATED.

The practical value of a preservative depends very largely upon the conditions under which it is used, and investigations to determine its value must necessarily be broad. The following points were considered in the tests:

(1) The important chemical and physical properties of the preservative.

(2) The effect of the preservative on the strength of the wood treated with it.

(3) The ability of the preservative to penetrate and diffuse through wood.

(4) The permanency of the preservative after its injection into wood. This involves a study of its volatility and leachability.

(5) The combustibility of wood treated with the preservatives.

(6) The toxic efficiency of the preservative in preventing the growth of wood-destroying fungi.

(7) The corrosive action of the preservative on steel.

(8) The effect of the preservative on paint applied to the wood subsequent to treatment.

No systematic tests were made on the effect of the preservative as an electrolyte or in contaminating drinking water, nor any tests which relate to a special or limited use.

METHODS OF TEST.

The various tests were conducted as follows:

Thoroughly air-seasoned eastern hemlock (*Tsuga canadensis* L.) was selected as the wood best suited for the experiment because of its low inherent resistance to attack by fungi, the comparative uniformity with which it can be treated, and its availability. Only perfectly clear, straight-grained, and uniform material, free from all

mechanical and physical defects, was used. The pieces selected for test were 12 by 26 by 1¼ inches. These were cut and numbered as shown in *A*, Plate I. Some of the test specimens were left untreated; others after treatment were recut and renumbered as shown in *B*, Plate I.

The uses to which the specimens were put are given in the description of each test.

CHEMICAL AND PHYSICAL PROPERTIES OF THE PRESERVATIVES.

The chemical composition of each preservative, its specific gravity, viscosity, odor, flash, and burning points were tested by standard methods. In all distillations the apparatus described in Forest Service Circular 112 was used.

The specific gravity was determined chiefly by a hydrometer or by a Westphal balance. Viscosities were obtained by using the Engler orifice viscosimeter at various temperatures. The flash and burning points were determined by heating the preservative at a rate of 2° C. per minute in an open flash-point tester, passing a small flame over the surface every minute.

METHOD OF TREATING WITH PRESERVATIVE.

Pieces Nos. 4, 5, 6, 7, 12, 13, and 14–2 were treated with the various preservatives in an impregnation cylinder. Before treatment they were oven-dried at 100° C. in order to be sure that all specimens were as nearly as possible in a uniform moisture condition. They were then weighed and impregnated. The simplest procedure of treatment was followed. For example: After the wood was placed in the cylinder the preservative was admitted, displacing the air, until the cylinder was completely filled; a pressure of about 50 pounds per square inch was then applied until the desired absorption was obtained, when the cylinder was drained of excess preservative and the specimens removed and weighed within 24 hours. When necessary higher pressures than 50 pounds were used.

STRENGTH TESTS.

Pieces 1, 2, and 3, which were not treated, and 4, 5, and 6 (see *A*, Pl. I), which were treated with the preservative, were tested in bending to failure in an ordinary 30,000-pound testing machine, using a center load over a 12-inch span. Care was taken to have all specimens at approximately the same moisture content at the time of test (about 6 per cent) by allowing them to remain in the laboratory until they no longer absorbed moisture from the air. Specimens treated with oils usually contained a little less moisture than those untreated. After being broken, 3-inch specimens were cut from each end for fungus-pit tests (see *B*, Pl. I).

PENETRANCE OF THE PRESERVATIVE INTO WOOD.

The distribution of a preservative in the wood, a most important feature in any treatment, was studied as follows:

The central portions of sticks 4, 5, and 6, after the strength data had been obtained on them, were split, and the depth and character of the penetration recorded. This could usually be done visually, but with those preservatives which in aqueous solution were colorless, an aniline dye was used or the specimens were chemically analyzed.[1]

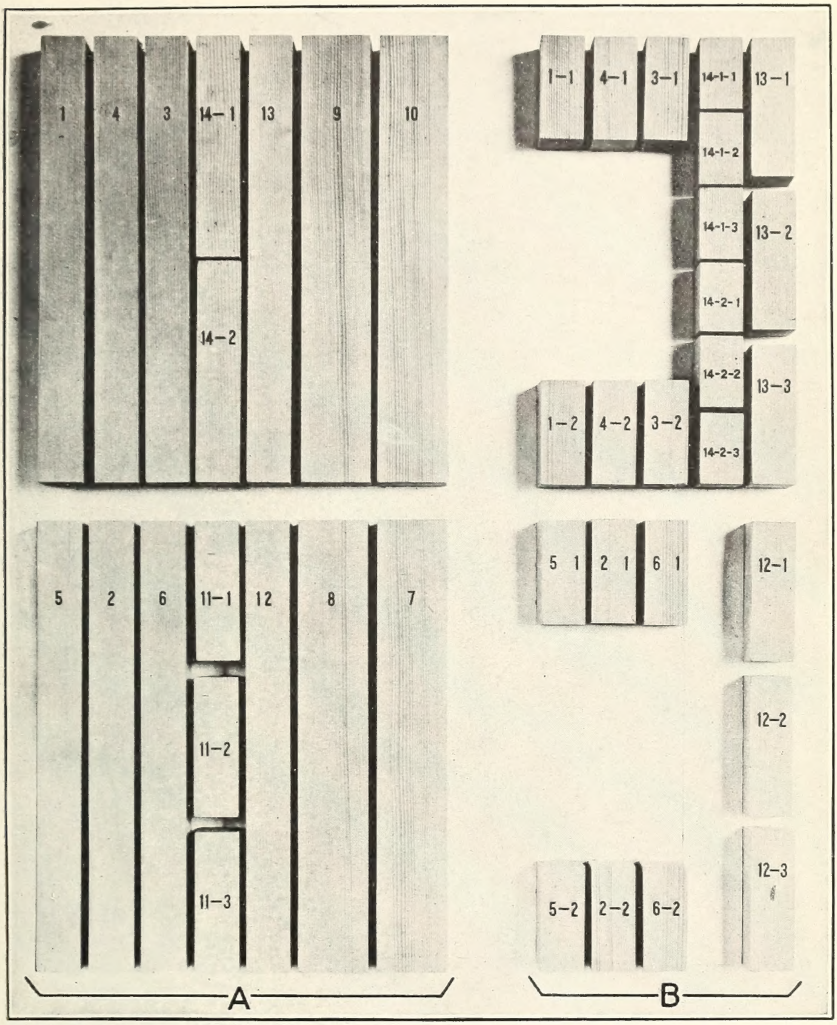
The results from these tests were used to supplement those secured from pieces 8, 9, and 10, which were tested in a specially-constructed penetrance apparatus (see Pl. II) operated in the following manner: A hole 1 inch in diameter was bored in the center of each stick (*A*) to a depth of three-fourths inch. The stick was then placed on the shelf (*B*) inside the apparatus for several hours, and after being weighed was clamped between two iron disks (*C* and *D*) so that the preservative could be forced into the hole from the tank (*E*) under a constant pressure and temperature. The stick was raised to a temperature of about 180° F. by the steam coils (*F*) before the preservative was admitted. The pressure was controlled by compressed air on the top of the preservative in tank (*E*). For oils, the length of the pressure period was 30 minutes, and for water-soluble salts 3 minutes, with the exception of sodium silicate, for which the time was prolonged to 30 minutes. The time it took to penetrate the wood longitudinally was noted.[2] At the end of these periods the specimen was sawed longitudinally and transversely through the center lines and the penetration radially, tangentially, and longitudinally was studied. (See Pl. III.)

VOLATILITY TESTS.

The volatility tests on oils were made to determine only the relative rates at which they left the treated wood. The plan of using matched pieces, as outlined in Plate I, was abandoned because the data obtained were inaccurate, the specimens reabsorbing moisture through the untreated end surfaces of the specimens cut after treatment. A new set of specimens was prepared from noble fir (each 1¼ by 2 by 6 inches) and treated for the volatility experiments. These were weighed separately and placed in the volatility apparatus (fig. 1), consisting of an air-tight metal box, 15 by 24 by 30 inches, through which a constant current of air, partially dehydrated by passing through calcium chloride towers, was drawn.

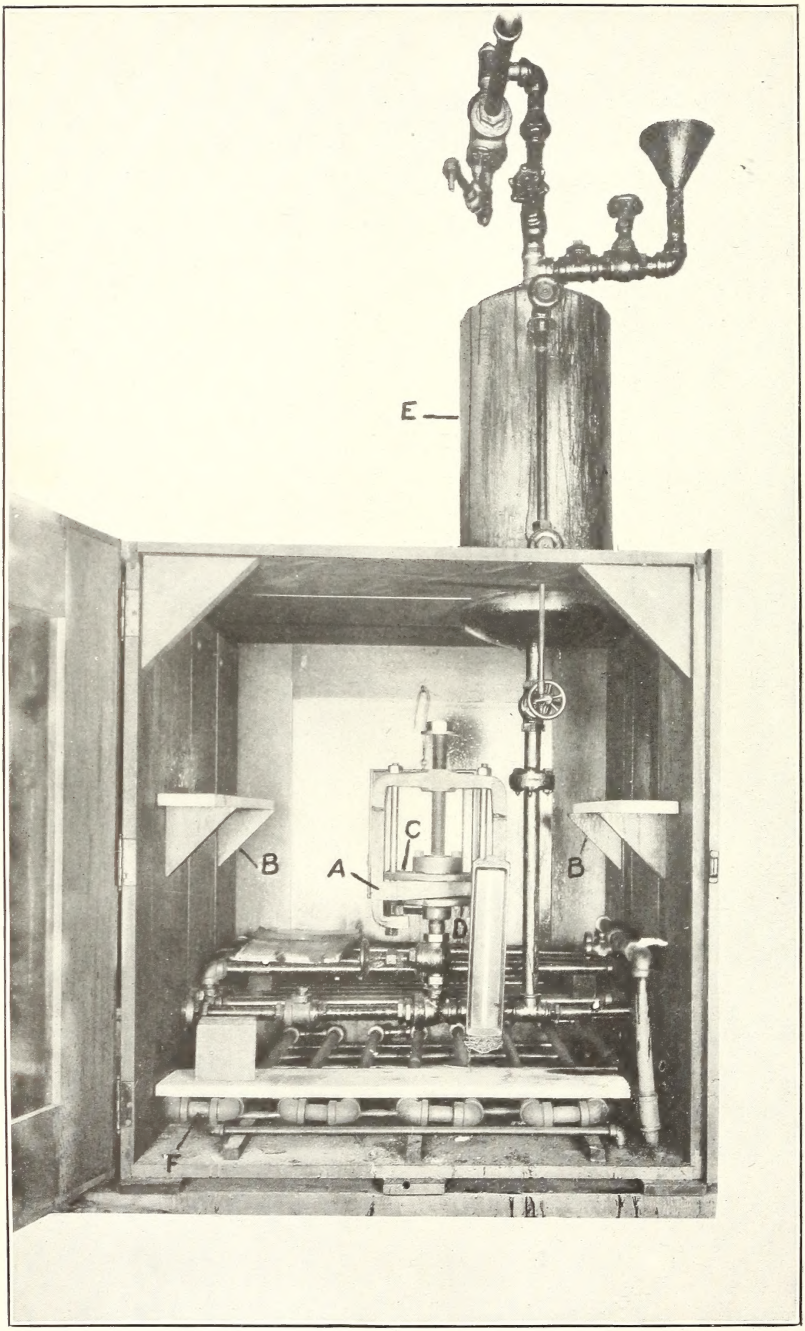
[1] It was found by repeated tests that water and the dye had a tendency to penetrate in some cases slightly farther than the preservative, although the difference was of no practical significance.

[2] A mirror placed in the back of the apparatus enabled the penetration in the rear end of the stick to be determined.

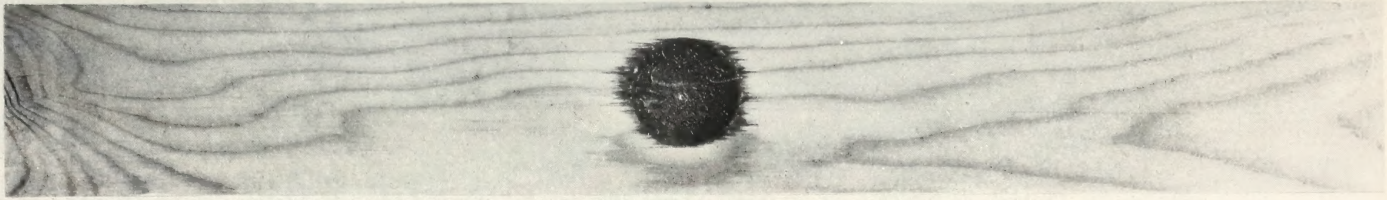


A.—Specimens cut thus before treatment. B.—Specimens cut thus after treatment.

METHOD OF MATCHING AND CUTTING SPECIMENS.

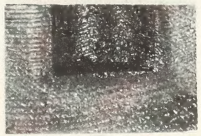


APPARATUS FOR CONDUCTING TESTS ON PENETRANCE.



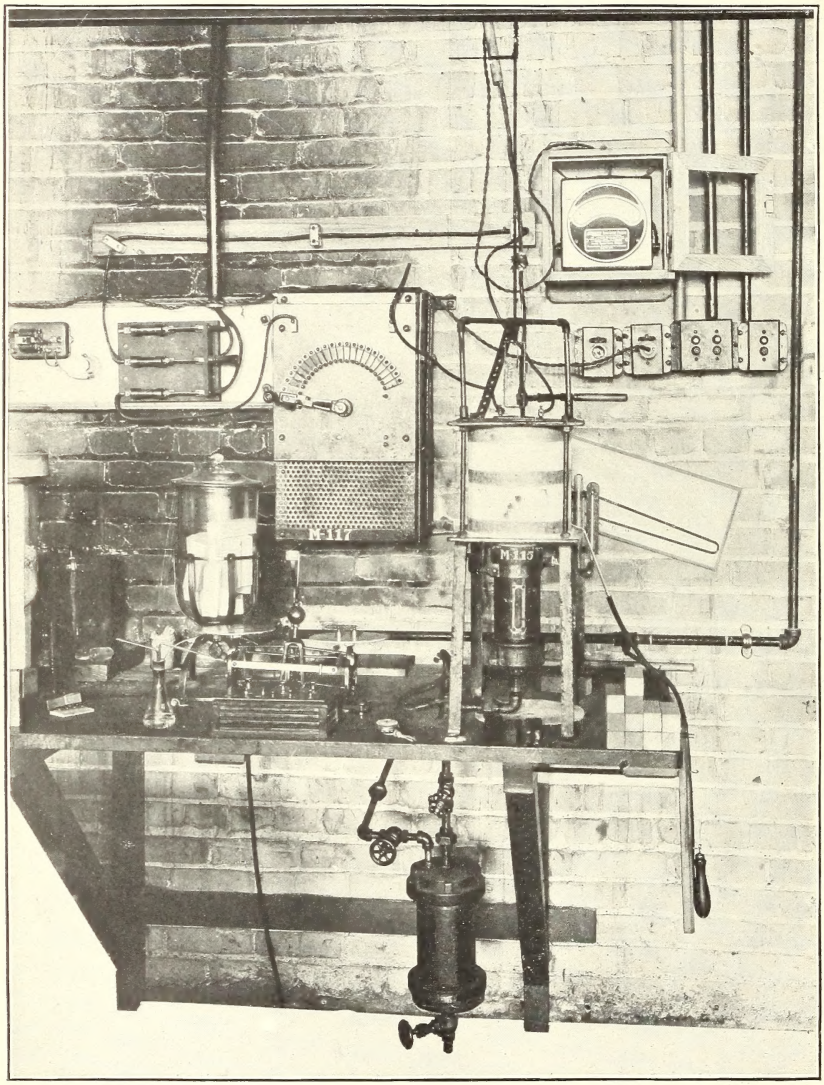
1

2



3

PENETRANCE SPECIMENS AFTER TREATMENT. 1. BEFORE BEING CUT. 2. CUT LONGITUDINALLY. 3. CUT TRANSVERSELY.



APPARATUS FOR DETERMINING RELATIVE INFLAMMABILITY.

The box was heated to 30° C. by electric lamps, the temperature being automatically controlled within 1° C. by a thermostat. The treated specimens were removed and weighed at weekly periods for 3 months, the loss in weight being taken as representing the amount of the preservative volatilized.

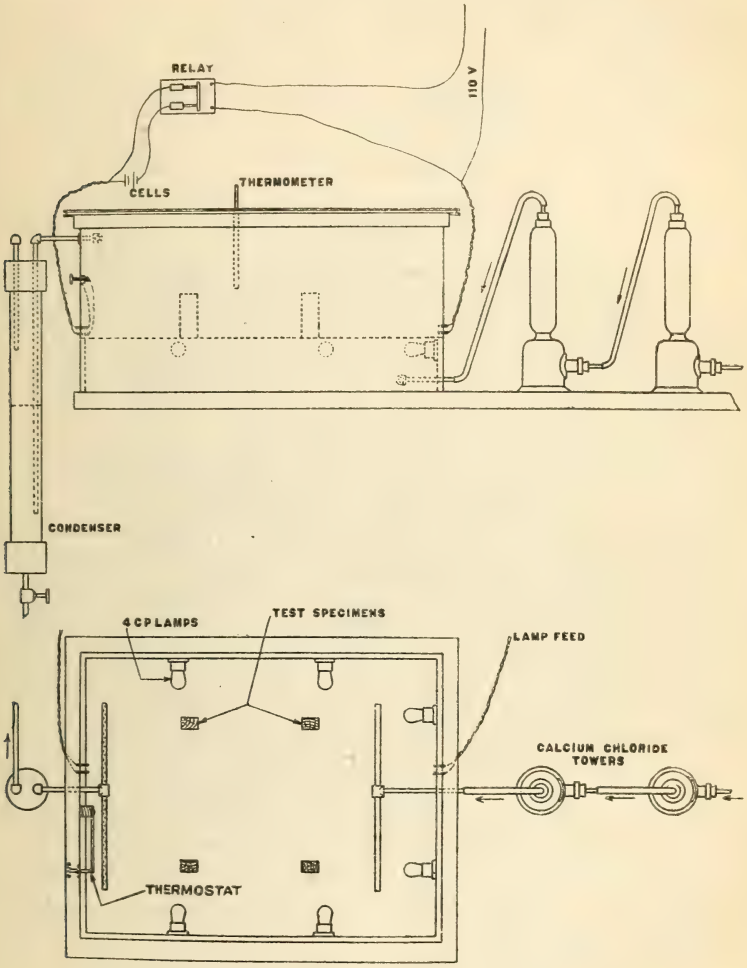


FIG. 1.—Apparatus for conducting tests on volatility.

LEACHING TESTS.

Tests were made on the water-soluble salts to determine the relative rates with which they leached from the treated wood. As soon as possible after treatment stick 12 was recut into three pieces, each $1\frac{1}{4}$ by $1\frac{1}{4}$ by 4 inches in size, and weighed separately to determine the amount of preservative it contained.

The test pieces were then submerged in a glass jar containing 300 c. c. of distilled water at room temperature. This water was changed at stated intervals and analyzed for the presence of preservative. The total time of leaching was 4 weeks. To check the amount of preservative remaining in the wood after the total submersion period the specimens were shredded and chemically analyzed. Owing to the large amount of preservative which adhered to the surface of the wood, and the absorption of some of it, it was extremely difficult to secure satisfactory results on leaching. For this reason no values are given. Recent experiments indicate that not only do the different salts leach at different rates, but also various concentrations of the same salt.

INFLAMMABILITY TESTS.

The crib and shaving tests frequently used in testing the combustibility of wood proved unsatisfactory, and a new form of apparatus was finally developed with which more comparable results were obtained. This apparatus (see Pl. IV) consists of a silica tube, wrapped with nichrome ribbon. An iron tube fitted with a mica sight was cemented below the silica tube.

The specimen of wood, after being lowered in the silica tube, was heated at a uniform rate by passing 24 amperes of electric current at 110 volts through the nichrome ribbon. Temperature readings were obtained from a thermocouple placed beside the specimen and reading direct from a Hoskins pyrometer indicator. A pilot light was used to ignite the gases distilled from the wood. Compressed air partially dehydrated by expansion was passed through the apparatus, its intensity being indicated by a sensitive liquid manometer. Three untreated test specimens cut from stick 11 (see Pl. I) were burned as a check against the three treated specimens cut from stick 13. When the preservative was a water-soluble salt, the test specimens were first air-dried and then oven-dried before ignition. When the preservative was an oil, one inflammability test was made within 24 hours after impregnation and another after three months' seasoning in the volatility apparatus, the latter being made on specimens cut from stick 12.[1]

TOXICITY TESTS.

Because of the importance of toxicity tests and the inherent objections to various established methods of testing, three independent methods were followed:

(1) Petri-dish method, in which the preservative is mixed with a culture medium and inoculated with fungi.

[1] Stick 12 was used for leaching tests in the treatments with water-soluble salts, and for inflammability tests after 3 months' seasoning in the volatility apparatus in the treatments with oils.

(2) The injection of the preservative into wood, with a subsequent exposure to pure cultures of wood-destroying fungi in sterilized jars. Specimens recut from stick 14, as indicated in *B*, Plate I, are being used for these tests.

(3) The injection of the preservative into wood with subsequent exposure to various fungi in a fungus pit. Specimens recut from sticks 1 to 6, inclusive, as indicated in *B*, Plate I, are being used for these tests.

At present tests by the petri-dish method are the only series that have advanced far enough to be reported upon.

PETRI-DISH TESTS.

In these tests the culture medium consisted of the extract of 1 pound of lean beef in 1,000 c. c. distilled water, to which is added 25 grams Löfflunds malt extract and 20 grams agar-agar.

The medium and preservatives were sterilized at 100° C. in separate sealed containers, then thoroughly mixed together and poured into petri dishes 100 mm. in diameter and 10 mm. deep. (See Pl. V.) After hardening, the agar-preservative mixture was inoculated at the center with the mycelium of a wood-destroying fungus (see Pl. V), and the cultures then placed in an incubator held at approximately 25° C. for from 4 to 6 weeks. The growth was observed usually at intervals of about a week. Plate V shows the appearance of these cultures of fungi in various stages of development. This test is considered by the Forest Service as merely tentative. While it is open to certain objections, such as the possible chemical combination of certain of the preservatives or their constituents with the media, it nevertheless offers considerable advantage in giving quick indications of the toxicity of a substance, in that way indicating the most promising preservatives for further work.

The results of tests to date on the fungi *Fomes annosus* (Fr.) Cke. and *Fomes pinicola* (Sw.) Fr. are summarized in Table 5.[1]

CORROSION TESTS.

To determine the corrosive action of the preservative on steel, so that possible deterioration in a treating cylinder might be ascertained, a strip of boiler flange steel of the quality specified by the American Society for Testing Materials, August 16, 1909, was submerged in the preservative and heated to a constant temperature of about 98° C. The preservative was changed every week for 4 weeks in the case of oils; with aqueous solutions, it was changed every day for 1 week. The difference in the weight of the steel before and after

[1] Concentrations in this table are based on the actual *weight* of preservative in 20 c. c. agar-preservative mixture.

submersion was taken to indicate its corrosion. All depositions on the surface of the metal were removed as nearly as possible with a rubber "policeman" each time the preservative was changed. At the end of the tests, where electrolytic deposition of metal had taken place, the deposited metal was removed by acid and its amount determined by an analysis of the acid solution. The weight of deposited metal thus determined was added to the loss of iron, and this total represented the total corrosion. The figures thus obtained were then calculated to ounces of steel corroded per square foot of surface exposed per week.

PAINT TESTS.

The treated wood was first air-seasoned for about 1 month to permit water and light oils to evaporate, and then coated with white paint (30 pounds of lead oxide to 1 gallon of linseed oil), noting the color change which subsequently took place. This test was made in order to determine the practicability of painting treated wood.

The results of the tests on wood treated with water-soluble salts were favorable, and the scope of the tests was therefore enlarged.

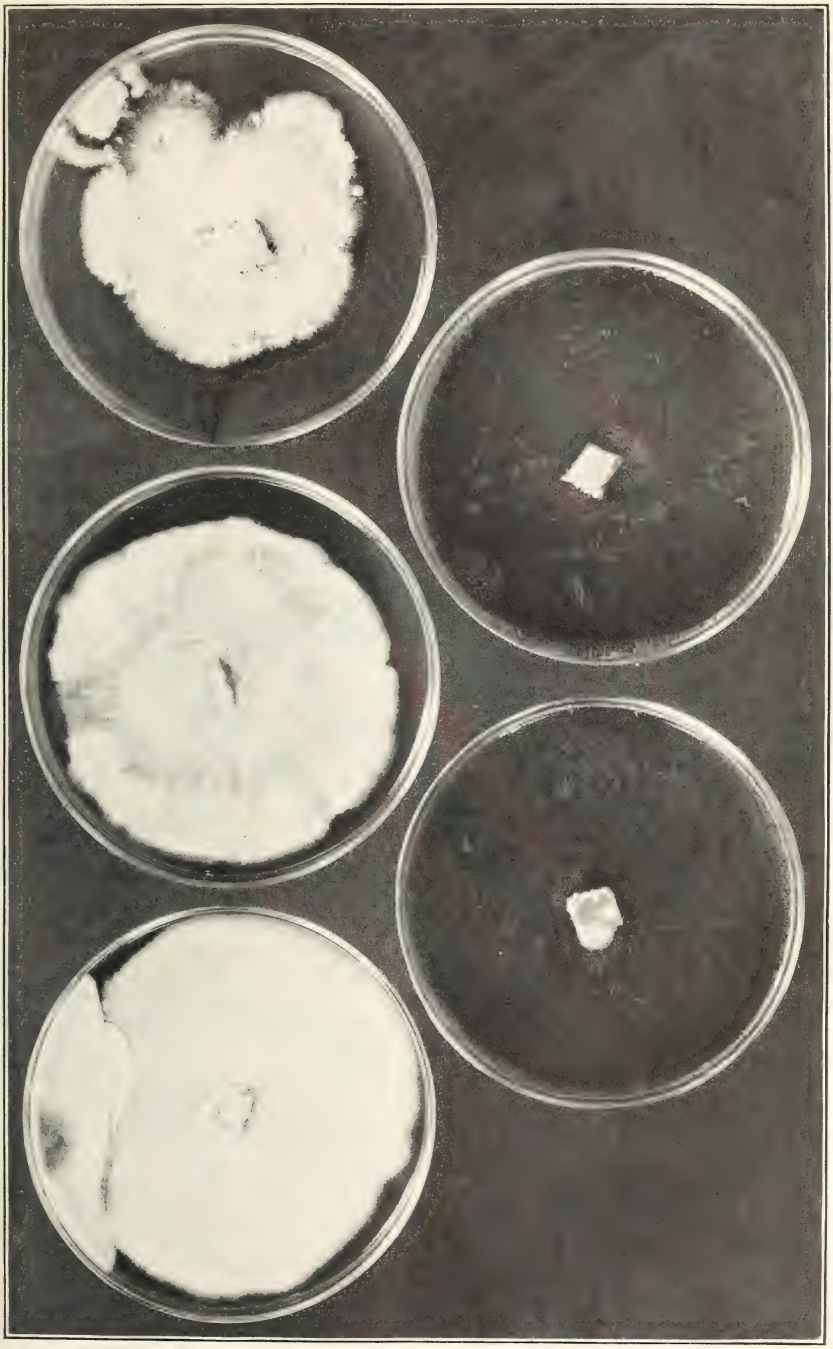
Specimens of noble fir, 1 by 4 by 12 inches, were treated with zinc chloride and sodium fluoride, and painted with white-lead paint. Untreated specimens were also painted for comparison. Four specimens were used in each set. One specimen from each series was placed in running water or in the moist atmosphere in the fungus pit, and two exposed to the weather.

These tests also indicated that wood treated with these salts could be successfully painted, and arrangements were then made with the National Paint Manufacturers' Association for a more extensive test.

White pine panels, 2 by 3 feet by 1 inch, were treated with zinc chloride, sodium fluoride, and ammonium phosphate. Six panels were treated with each preservative and six were used untreated. These were sent to the Institute of Industrial Research, Washington, D. C., where they were painted under the direction of Mr. Henry A. Gardner, representing the National Paint Manufacturers' Association. After painting, the panels were divided into three sets—one of which is exposed at Atlantic City, N. J., one at Washington, D. C., and the third at St. Louis, Mo., under the direction of Dr. Hermann von Schrenk.

RESULTS.

The results secured from the experiments may be changed by subsequent tests, since the field covered is new and errors in manipulation, not at present apparent, might exist. Every feasible precaution was taken, however, to avoid errors, and those known and uncontrollable are mentioned.



PETRI-DISH TESTS SHOWING RETARDATION OF GROWTH AS THE PER CENT OF TOXIC AGENT IS INCREASED.

PHYSICAL AND CHEMICAL PROPERTIES.

The results of the tests on physical and chemical properties are given in Table 1.

EFFECT OF THE PRESERVATIVE ON THE STRENGTH OF WOOD.

Table 2 gives the results of the tests on the effect of the preservative on the strength of wood.

As a greater accuracy than plus or minus 10 per cent could not be obtained in these tests, largely because of variables inherent in wood, the conclusions should be interpreted liberally.

All of the preserving oils, viz, the products of coal tar, wood tars, water-gas tars, and crude petroleum produced no appreciable weakening in the strength of the wood impregnated with them. The amount of moisture which the treated specimens contained could not be definitely determined, although it is believed that it was slightly less than the moisture in the untreated specimen. The variations in individual cases from the average is within the limit of accuracy of the test. An average of all the tests indicates that the strengths treated and untreated were about the same.

In general, the water-soluble preservatives caused a slight weakening of the seasoned wood. This was most pronounced in the case of sodium silicate and by-product zinc sulphate. The values given for the effect of these preservatives are accentuated, due to the higher moisture content of the treated pieces. The application of a moisture-correction factor would probably show that, with the exception of sodium silicate and by-product zinc sulphate, the weakening caused by the water-soluble preservatives is of no practical significance. The specimens treated with sodium silicate, however, were noticeably affected, the outer wood fibers being badly checked and disintegrated.

PENETRANCE OF THE PRESERVATIVE INTO WOOD.

Table 2 gives the results obtained on the penetrance of the preservative into wood.

So far as penetrance is concerned, the following preservatives can be considered satisfactory: Coal-tar creosote, coal-tar creosote fractions I, II, III, and IV, the three water-gas-tar creosotes, S. P. F. and Avenarius carbolineums, C. A. wood preserver, beechwood creosote, Spirittine, wood-creosote oil, copperized oil, fuel oil, kerosene, zinc chloride, commercial zinc sulphate, by-product zinc sulphate, B. M. preservative, sodium fluoride, and cresol calcium.

Wood tar from Douglas fir, Preservol, and coal-tar creosote fraction V were very difficult to force through hemlock, being more than twice as resistant as coal-tar creosote.

Satisfactory penetrations with hardwood tar, Timberasphalt, and sodium silicate were not secured. The results indicated that they were from 10 to 18 times as resistant to penetration into hemlock as the coal-tar creosote used.

PERMANENCE OF THE PRESERVATIVE AFTER INJECTION INTO WOOD.

Table 3 gives the results obtained from the volatility tests.

After 10 weeks' exposure the preservatives had lost amounts varying from 1 to nearly 60 per cent. The loss was proportional to the content of low-boiling oils, as shown by analysis, those having low distillation points losing the most by volatilization.

The oils losing excessively by volatilization were the first two fractions of coal-tar creosote, water-gas-tar creosote (specific gravity 1.012), and kerosene. The high volatility of these oils separates them from the more efficient wood preservatives.

Those losing moderately by volatilization were coal-tar creosote fractions III and IV, coal-tar creosote, water-gas-tar creosote (sp. gr. 1.051), wood tar from Douglas fir, wood-creosote oil, beechwood creosote, Preservol, and fuel oil.

The least volatile of the oils tested were coal-tar creosote fraction V, water-gas-tar creosote (specific gravity 1.07), Avenarius carbolineum, S. P. F. carbolineum, C. A. wood preserver, hardwood tar, Spirittine, and Timberasphalt. Some difficulty was experienced in obtaining reliable data upon these oils, due to their nonvolatile character. There was a tendency for the specimens to absorb small quantities of moisture, which obscured the results somewhat. The data show, however, that the oils just mentioned were much less volatile, and therefore more permanent in the wood exposed to the air than those listed in the two preceding paragraphs.

The lighter fractions of coal-tar creosote were more highly toxic than the very heavy fractions. It is especially necessary in the case of oils, therefore, that the toxic properties should be considered in conjunction with the permanence of the preservative. The higher toxicity and greater volatility of low-boiling creosote oils and the lower toxicity and lower volatility of the high-boiling creosote oils tend to balance each other. This point has been substantiated in service tests in which coal-tar creosote proved practically as efficient in preventing decay as the higher boiling creosote derivatives.[1]

EFFECT OF THE PRESERVATIVE ON THE COMBUSTIBILITY OF WOOD.

Table 4 gives the results obtained in the inflammability tests.

Wood treated with the oils in every case ignited at lower temperatures than untreated wood. When permitted to air-season for

[1] See article Eng. News, Nov. 27, 1913, "Condition of experimental poles in the Augusta-Savannah and Helena-Meldrim lines," and Forest Service Circular 198.

3 months the temperature of ignition was considerably raised, due probably to the evaporation of the more volatile constituents. The loss in weight from burning treated wood seasoned for 3 months was also usually less than in the specimens burned shortly after impregnation.

In general, wood treated with oils ignited at lower temperatures than wood treated with water-soluble preservatives. The temperature of ignition in both cases was lower than that of untreated wood.[1] Furthermore, wood treated with oils showed in general greater loss in weight after combustion than wood treated with the water-soluble salts. It should be noted, however, that the amount of wood actually burned may have been less than in the case of the salts.

Untreated wood and wood treated with oils (exception, Timber-asphalt) burned freely, and in general had to be extinguished after a three-minute period, while wood treated with water-soluble salts (exception, cresol calcium) burned slowly and became extinguished in less than three minutes.

TOXIC EFFICIENCY OF THE PRESERVATIVE IN INHIBITING FUNGOUS GROWTH.

Table 5 [2] contains the results of the tests thus far completed on toxicity. The following conclusions on the toxicity of the various preservatives should not be considered as absolutely final, because of errors peculiar to the Petri-dish method.

The products obtained from the high-boiling constituents of coal-tar creosote, for example, the carbolineums and high-boiling creosote fractions, were much less toxic than the coal-tar creosote or the low-boiling fractions. The products with the greater toxic properties are those having the lower specific gravities and lower boiling points.

The same was true to an exaggerated degree in the water-gas-tar creosotes, the 1.012 oil being about as toxic as coal-tar creosote, while the 1.07 oil was only slightly toxic.

The hardwood tar and Spirittine (from yellow pine) were less than half as toxic as coal-tar creosote. Wood tar from Douglas fir and Preservol were about equal to coal-tar creosote in toxicity. Beech-wood creosote was more than twice as toxic as coal-tar creosote.

Of the water-soluble salts tested sodium fluoride was the most highly toxic, being from one and one-half to two times as toxic as coal-tar creosote. Zinc chloride was slightly more toxic to *Fomes annosus*, but far less toxic to *Fomes pinicola* than coal-tar creosote. Cresol calcium was also very highly toxic, being from two to four

[1] Wood dipped in a 50 per cent sodium silicate solution ignited at a temperature of 448° C., and its weight was reduced 17 per cent, although burning immediately ceased when the sample was dropped in the lower chamber of the inflammability apparatus.

[2] This table was published in the Jour. Ind. and Eng. Chem., Feb., 1914, by C. J. Humphrey and Ruth Fleming, who conducted the tests. They are included here because they are an important factor in determining the value of these preservatives.

times as much so as coal-tar creosote. Sapwood antiseptic was almost nontoxic.

Preservatives designated as copperized oil, fuel oil, Timberasphalt, kerosene, and N. S. Special had very low toxic properties.

CORROSIVE ACTION OF THE PRESERVATIVE ON FLANGE STEEL.

Of the various preservatives tested, coal-tar creosote, copperized oil, the fractions of coal-tar creosote, the various carbolineums, the water-gas-tar products, fuel oil, Timberasphalt, and kerosene had very slight corrosive action on steel. In practical operations such action can very probably be neglected.

The metallic salts, except cresol calcium and sodium fluoride, were much more pronounced in their action than coal-tar creosote, so that the depreciation in plants using them would seem to be much greater. The corrosive action of cresol calcium is much less than the other salts tested. Zinc sulphate was much less corrosive than zinc chloride.

The very marked corrosion of hardwood tar, Preservol, and tar from Douglas fir is probably due to the comparatively large amount of acetic and other organic acids which they contain, while the somewhat less corrosive action of Spirittine and beechwood creosote are probably due to smaller quantities of these acids.

In general, wood-tar products were much more corrosive than coal-tar or petroleum products. This property may, however, be largely eliminated in the future development in methods of refining these oils.

DISCOLORATION OF PAINTED WOOD.

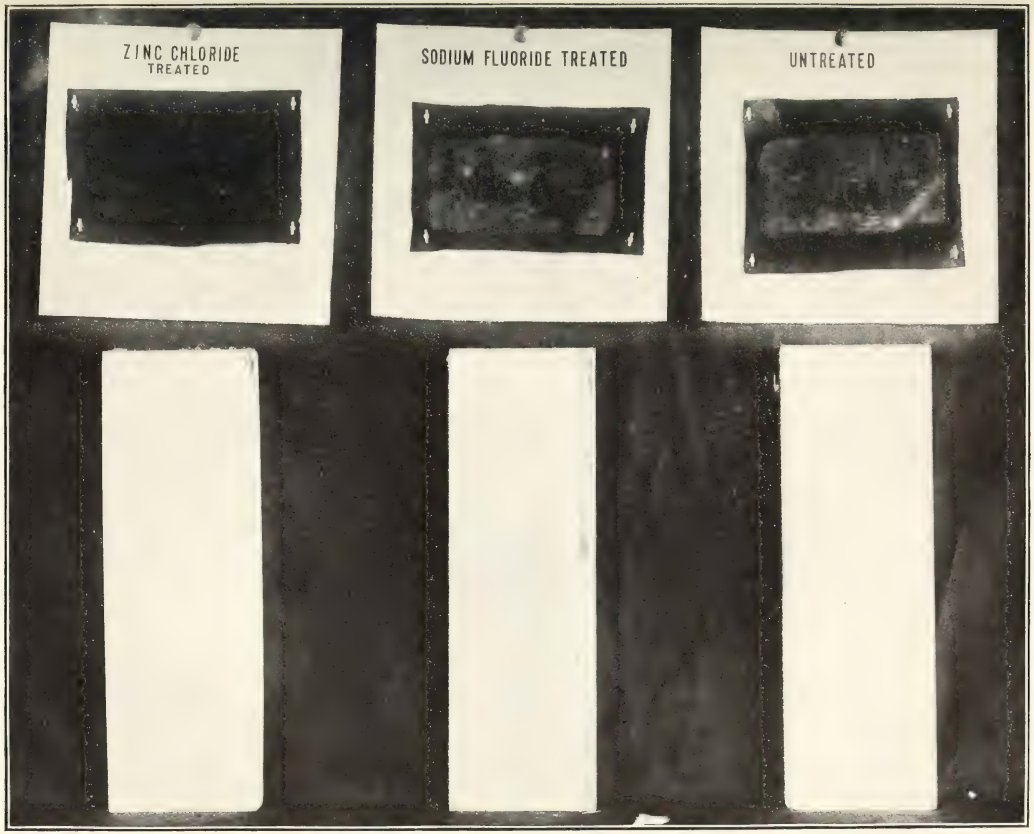
All of the oils tested rendered the wood unfit for subsequent painting.[1] Copperized oil was least objectionable in this respect. If thoroughly dried after treatment, so that excess oil would not appear on the surface, it is possible that wood treated with some of these preservatives could be satisfactorily painted with dark pigments.

The water-soluble salts were all satisfactory (except sodium silicate and cresol calcium) in that they caused no discoloration and apparently no deterioration of the painted surface. From the results of tests thus far made it is likely that woods treated with zinc chloride and many water-soluble salts can be successfully painted.

Cresol calcium caused discoloration of the paint; sodium silicate reacted with the oil of the paint film, causing it to lose its adhering properties.

Additional tests on the effect of zinc chloride and sodium fluoride on white-lead paint were made. Specimens exposed to the weather were in good condition after 2½ months, when they were accidentally destroyed. Specimens placed in moist air were in good condition after 1 year and 4 months. No difference was noticeable between

[1] This applies, of course, only to the method of painting herein described.



EFFECT OF TREATMENT ON PAINT COATINGS.

[Specimens immersed in water at 70° F. for 1 year and 4 months. Upper portion shows degree of chalking of paint when rubbed with a dark cloth.]

the treated and untreated specimens; there was no visible evidence of the hygroscopic action of zinc chloride on the paint film, nor did the salt appear to come to the surface. There was a marked difference in the appearance of the treated and untreated specimens that were placed in running water for 1 year and 4 months. (See Pl. VI.) The paint film on the one treated with sodium fluoride and the untreated one had disintegrated and could be rubbed off upon a cloth (see Pl. VI, at top); that on the specimen treated with zinc chloride was in good condition. This indicates that zinc chloride may have a preservative action upon paint films under certain circumstances.

No results have thus far been obtained from the last series of tests made in cooperation with the National Paint Manufacturers' Association.

The results of the tests thus far made indicate that woods treated with zinc chloride, sodium fluoride, and other water-soluble salts might be successfully painted. This point can not be definitely settled, however, until the results of the tests in cooperation with the National Paint Manufacturers' Association become available.

CONCLUSIONS.

In general, highly viscous oils do not readily penetrate, while oils with low viscosities penetrate wood readily. As temperature strongly influences the viscosity of oils, and as the diffusion of the preservative through the wood is one of the most important factors in proper treatment, to secure best results both the wood and the preservative should be sufficiently heated during the pressure period. Because of the low thermal conductivity of wood the treatments should not be made too rapidly. With water-soluble salts these precautions are not important.

With coal-tar creosote it appears that the fractions of greater stability are the less toxic. Present practice rather favors the retention in treated wood of the more volatile fractions by an admixture of the more stable ones. If the toxic values here given are correct, there is, in practice, being forced into wood about one and one-half times as much zinc chloride and from 10 to 20 times as much coal-tar creosote as is necessary to prevent decay. Of course, in practice more preservative than these toxic minima must be forced into wood in order to make proper allowance for any subsequent changes that might take place. However, more economic results, especially when decay is accompanied by mechanical deterioration, can be secured by diffusing the preservative more thoroughly through the wood than by saturating the outer fibers and attempting to retain in the wood the volatile constituents through admixtures of non-

volatile constituents. It also appears that the factor of safety in zinc-chloride treatments is very low, and that to secure the best results more than 0.4 to 0.5 pound per cubic foot, the present practice, should be injected.

In general, the flash or burning point of an oil affects the inflammability of wood treated with it. Of greater importance, however, is the length of time the treated wood has seasoned, as a prolonged seasoning of such wood raises considerably its ignition temperature. It would seem good practice first to season such treated timber before placing it in positions subject to fire. While wood treated with the water-soluble salts mentioned in these tests was in general less difficult to ignite than untreated wood, nevertheless the presence of such preservatives usually renders the wood slow burning and easily extinguishable.

In using the data submitted in this bulletin, the reader is cautioned against drawing sweeping conclusions. It was possible to make only a limited number of check determinations because of the many variables which had to be considered. The most reliable information on the efficiency of preservatives is, of course, obtained from service tests, but until such data become available, it is thought that the tests already described will be found valuable in studying the most efficient use of wood preservatives.

TABLE 1.—*Physical and chemical properties of the preservatives.*

Preservative No.	Preservative designated by cooperator as—	Specific gravity.	Temperature at specific gravity.	Flash point.	Burning point.	Viscosity temperature (°C.).				Odor.	Remarks.
						10	30	50	95		
			°C.	°C.	°C.						
1	Coal-tar creosote	1.048	60	93	100	3.10	1.70	1.40	1.10	Strong creosote	Graded as C.
2	Coal-tar creosote, Fraction I	0.931	60	62	69	.....	1.10	1.00	.95	Like toluene	Includes oils distilling between 0° and 205° C.
3	Coal-tar creosote, Fraction II	1.003	60	79	85	.....	.....	.....	1.00	Strong like naphthalene	Includes oils distilling between 205° and 250° C. Solid at room temperature.
4	Coal-tar creosote, Fraction III	1.045	60	103	110	2.45	1.40	1.20	1.10	Strong coal-tar creosote	Includes oils distilling between 250° and 295° C.
5	Coal-tar creosote, Fraction IV	1.088	60	130	136	.....	.....	1.51	1.11	Mild coal-tar creosote	Includes oils distilling between 295° and 320° C. Would not flow at 30° C.
6	Coal-tar creosote, Fraction V	1.150	60	172	178	.....	.....	80.00	2.60	.....do	Includes residue above 320° C.
7	Water-gas-tar creosote, 1.051	1.042	60	72	93	.....	1.70	1.40	[1] 1.10	Like illuminating gas	A distillate of water-gas tar.
8	Water-gas-tar creosote, 1.012	0.985	60	81	93	.....	1.20	1.10	[2] 1.00	.....do	Do.
9	Water-gas-tar creosote, 1.070	1.058	60	48	65	16.00	3.70	2.00	1.20	Like kerosene	A water-gas-tar product.
10	S. P. F. carbolineum	1.127	16	133	157	.....	4.40	2.30	1.25	Tarry (mild)	These compounds are similar in many respects.
11	Avenarius carbolineum	1.126	16.5	139	166	.....	7.50	2.40	1.25	Tarry	
12	C. A. wood preserver	1.120	60	142	165	.....	5.50	2.00	1.10	Not distinctive	High-boiling coal-tar products.
13	Hardwood tar	1.195	60	90	[3]	.....	17.50	6.30	1.40	Disagreeable pyroligneous.	
14	Wood tar (Douglas fir)	1.052	60	45	85	.....	15.20	4.90	1.40	.....do	This resembles a tar more than a creosote.
15	Beechwood creosote	1.040	60	88	96	[4] 5.80	3.40	1.90	1.20	Like pyroligneous acid	A refined product of beechwood tar. Contained 3.2 per cent tar acids.
16	Spirittine	1.006	60	74	77	.....	4.20	1.90	1.20	.....do	A product of the distillation of southern pine.
17	Preservol	1.170	60	[5]	[5]	.....	[6]	5.90	1.50	.....do	Hardwood tar dissolved in water-contained pyroligneous acid.
18	Wood-creosote oil	1.032	60	87	94	.....	4.70	1.90	1.20	.....do	A product of the distillation of southern pine.
19	Timberasphalt	1.063	60	240	260	.....	.....	99.20	5.20	Like crude oil	A residuum of petroleum.
20	Copperized oil	0.937	25	125	164	.....	18.00	5.10	1.50	Like crude oil (mild)	Contains 0.34 per cent copper.
21	Fuel oil	0.870	60	72	101	2.80	1.57	1.30	1.10	Like crude oil (strong)	A crude petroleum.

[1] 80° C.
[2] 85° C.
[3] Water boiled off, preventing burning.
[4] At 22° C.
[5] Not possible because of presence of 50 per cent water.
[6] Would not run at 27° C. Lowest temperature at which viscosity could be taken was 43° C., giving 7.9 viscosity at 70° C.—2.2.

TABLE 1.—*Physical and chemical properties of the preservatives*—Continued.

Preservative No.	Preservative designated by cooperator as—	Specific gravity.	Temperature at specific gravity.	Flash point.	Burning point.	Viscosity temperature (°C.).				Odor.	Remarks.
						10	30	50	95		
			°C.	°C.	°C.						
22	Kerosene	0.798	60	57	61	.....	1.10	1.00	0.90	Characteristic	A product of petroleum.
23	Zinc chloride	1.028	20	.....	.....	.....	.....	.....	.....	Odorless	Contained 2.67 per cent zinc chloride.
24	Zinc sulphate	1.033	20	.....	.....	.....	.....	.....	.....	do	Contained 5.9 per cent zinc sulphate $7H_2O$.
25	Zinc sulphate (by-product)	1.040	20	.....	.....	.....	.....	.....	.....	do	Contained 6.8 per cent zinc sulphate $7H_2O$.
26	B. M. preservative	1.025	20	.....	.....	.....	.....	.....	.....	do	Contained 0.93 per cent Al. sulphate, 1.8 per cent $ZnCl_2$.
27	Sapwood antiseptic	1.027	20	.....	.....	.....	.....	.....	.....	do	Contained 2.92 per cent NaCl, 0.246 per cent $CaSO_4$, 0.246 per cent $ZnSO_47H_2O$, 0.182 per cent $CuSO_45H_2O$, .06 per cent $FeSO_4H_2O$.
28	Sodium silicate	1.074	20	.....	.....	.....	.....	.....	.....	do	Contained 8.9 per cent sodium silicate.
29	Sodium fluoride	1.009	20	.....	.....	.....	.....	.....	.....	do	Contained 1.2 per cent sodium fluoride.
30	Cresol calcium	1.075	20	.....	.....	.....	.....	.....	.....	Like phenols	2.43 per cent cresol calcium solution.

TABLE 2.—*Penetrance of the preservatives and their effect on the strength of wood.*

Preservative No.	Preservative designated by cooperator as—	Penetration.				Average absorption of preservative per cubic foot.	Strength in per cent of modulus of rupture of untreated wood.	Moisture at test.	
		Radial and tangential.		Longitudinal.[1]				Untreated.	Treated.
		Maximum.	Minimum.	Maximum.	Minimum.				
		Inch.	*Inch.*	*Inches.*	*Inches.*	*Pounds.*	*Per cent.*	*Per cent.*	*Per cent.*
1	Coal-tar creosote	0.28	0.23	6.00	5.30	8.76	93	6.20	.....
2	Coal-tar creosote, Fraction I.	.45	.21	6.00	6.00	5.28	101	5.88	.....
3	Coal-tar creosote, Fraction II.	.45	.17	6.00	6.00	6.86	92	6.22	.....
4	Coal-tar creosote, Fraction III.	.45	.21	6.00	6.00	7.55	92	6.44	.....
5	Coal-tar creosote, Fraction IV.	.37	.18	6.00	5.50	7.33	96	6.43	.....
6	Coal-tar creosote, Fraction V.	.12	.07	3.80	1.20	2.00	90	6.29	.....
7	Water-gas-tar creosote, 1.051.	.45	.33	6.00	5.00	6.45	92	5.53	.....
8	Water-gas-tar creosote, 1.012.	.45	.42	6.00	5.30	7.18	90	6.18	.....
9	Water-gas-tar creosote, 1.070.	.10	.10	6.00	3.33	9.58	108	4.52	.....
10	S. P. F. carbolineum.	.37	.23	6.00	5.70	8.77	100	6.40	.....
11	Avenarius carbolineum.	.17	.12	6.00	5.30	8.08	109	6.81	.....
12	C. A. wood preserver.	.27	.20	6.00	4.70	8.43	100	6.99	.....
13	Hardwood tar	.03	.03	.92	.50	6.50	98	6.11	.....
14	Wood tar (Douglas fir).	.08	.08	3.58	2.33	2.82	107	5.80	.....
15	Beechwood creosote.	.36	.106	6.00	3.16	12.68	99	5.30	.....
16	Spirittine	.38	.18	6.00	4.50	8.09	96	6.95	.....
17	Preservol	.08	.05	3.75	1.50	6.27	107	6.24	.....
18	Wood-creosote oil	.37	.15	6.00	4.30	12.86	110	6.41	.....
19	Timberasphalt	.02	.02	.33	.33	5.68	106	6.68	.....
20	Copperized oil	.22	.22	6.00	4.08	8.58	101	5.49	.....
21	Fuel oil	.45	.43	6.00	6.00	12.70	117	.....	.....
22	Kerosene	.45	.30	6.00	6.00	14.51	90	5.18	.....
23	Zinc chloride	.10	.08	6.00	5.30	[2].43	88	7.13	9.35
24	Zinc sulphate	.10	.08	6.00	4.66	[3].96	89	5.14	9.60
25	Zinc sulphate (by-product).	.25	.17	6.00	4.66	[3]1.11	82	3.88	5.77
26	B. M. preservative	.13	.10	6.00	4.60	[3].50	85	5.16	9.48
27	Sapwood antiseptic	.....	.....	.....	.....	.....	.....	.....	.....
28	Sodium silicate	.05	.03	.46	.30	.99	82	6.42	7.38
29	Sodium fluoride	.10	.10	6.00	5.00	.20	85	5.82	8.70
30	Cresol calcium	.10	.10	6.00	3.30	.46	103	5.72	6.58

[1] A penetration of 6 inches was the maximum that could be secured longitudinally, 0.45 inch was the maximum radial and tangential. The absorptions here given have no reference to the data on penetrance.
[2] Dry salt. [3] For composition see Table 1.

TABLE 3.—*Permanence of the preservatives after injection into wood.*

Preservative No.	Preservative designated by cooperator as —	Volatility.					
		Per cent volatilized after seasoning for—					
		10 days.	20 days.	30 days.	50 days.	70 days.	90 days.
1	Coal-tar creosote	11	15	17	20	22	.....
2	Coal-tar creosote, Fraction I.	38	48	53	57	57	.....
3	Coal-tar creosote, Fraction II.	22	30	36	44	47	.....
4	Coal-tar creosote, Frac. III	13	21	28	34	37	.....
5	Coal-tar creosote, Fraction IV	8	11	14	18	20	.....
6	Coal-tar creosote, Fraction V	6	6	5	6	7	.....
7	Water-gas-tar creosote, 1.012.	16	26	32	41	45	.....
8	Water-gas-tar creosote, 1.051.	18	21	25	30	33	.....
9	Water-gas-tar creosote, 1.07..	2	3	3	4	5	.....
10	S. P. F. carbolineum	3	4	5	8	11	.....
11	Avenarius carbolineum.	.....	.....	.....	1	1	.....
12	C. A. wood preserver	−2	−2	.....	+1	+1	.....
13	Hardwood tar	.....	.....	2	6	6	.....
14	Wood tar (Douglas fir)	12	14	15	15	14	.....
15	Beechwood creosote	14	17	21	25	29	.....
16	Spirittine	1	3	5	7	8	.....
17	Preservol	11	15	16	16	17	.....
18	Wood-creosote oil	11	13	15	16	16	.....
19	Timberasphalt	.....	.....	−12	+1	0	.....
20	Copperized oil	5	5	5	5	4	.....
21	Fuel oil	2	4	7	11	13	.....
22	Kerosene	55	74	81	88	91	.....

TABLE 4.—*Inflammability of treated wood.*

Preservative No.	Preservative designated by cooperator as—	Temperature of ignition (° C.).		Loss in weight due to burning calculated in per cent of weight before ignition.		Character of combustion.
		Days after impregnation—		Days seasoned—		
		2	90	2	90	
	Untreated wood (hemlock)	320	.....	29	.....	Burned freely.
1	Coal-tar creosote	174	225	25	21	Burned freely; black smoke; easily extinguished.
2	Coal-tar creosote, Fraction I	133	306	23	33	Burned very freely; easily extinguished.
3	Coal-tar creosote, Fraction II	113	286	25	21	Burned freely; easily extinguished.
4	Coal-tar creosote, Fraction III	148	269	26	16	Did not burn as well as creosote; easily extinguished.
5	Coal-tar creosote, Fraction IV	183	223	33	21	Burned freely; extinguished with difficulty.
6	Coal-tar creosote, Fraction V	195	287	10	15	Ignited with difficulty; burned poorly; easily extinguished.
7	Water-gas-tar cresote, 1.051	172	231	24	19	Did not burn freely; easily extinguished.
8	Water-gas-tar creosote, 1.012	149	238	29	18	Burned freely; difficult to extinguish.
9	Water-gas-tar creosote, 1.070	231	243	40	31	Burned like Avenarius carbolineum.
10	S. P. F. carbolineum	243	263	26	19	Burned like coal-tar creosote, but not so freely.
11	Avenarius carbolineum	213	235	32	18	Do.
12	C. A. wood preserver	215	247	33	35	Burned like creosote.
13	Hardwood tar	190	241	29	30	Burned freely; dense black smoke.
14	Wood tar (Douglas fir)	167	217	36	26	Burned like coal-tar creosote.
15	Beechwood creosote	177	.....	34	19	Burned freely; black smoke; rather easy to extinguish.
16	Spirittine	194	247	37	29	Burned freely; difficult to extinguished.
17	Preservol	205	269	23	22	Did not burn as well as creosote; easily extinguished.
18	Wood-creosote oil	178	251	39	35	Burned very freely; very difficult to extinguish.
19	Timberasphalt	296	310	28	32	Did not burn freely.
20	Copperized oil	200	228	43	33	Burned like coal-tar cresote.
21	Fuel oil	167	241	36	27	Burned very freely; very difficult to extinguish.
22	Kerosene	126	231	37	17	Do.
23	Zinc chloride	.....	[1] 287	.....	19	Hard to ignite; burned poorly; easily extinguished.
24	Zinc sulphate	.....	[1] 304	.....	18	Do.
25	Zinc sulphate (by-product)	.....	[1] 298	.....	.....	Do.
26	B. M. preservative	.....	[1] 305	.....	18	More difficult to burn than zinc chloride.
27	Sapwood antiseptic	.....	.....	.....	.....	
28	Sodium silicate	.....	[2] 309	.....	10	More difficult to burn than B. M. preservative.
29	Sodium fluoride	.....	[1] 303	.....	25	Burned like zinc chloride.
30	Cresol calcium	.....	[1] 288	.....	29	Burned freely; white smoke; hard to extinguish.

[1] Woods treated with salts were ignited as soon as their moisture content was reduced by air-seasoning to 6 per cent, usually about 2 weeks after impregnation. For absorption of preservatives, see Table 3.
[2] See footnote 1, page 11.

NOTE.—All salts burned for less than 3 minutes; all oils burned for 3 minutes and were then extinguished.

TABLE 5.—*Toxicity of preservatives to Fomes annosus and Fomes pinicola.*[1]

Preservative No.	Preservative designated by cooperator as—	Killing point.							
		Fomes annosus.				Fomes pinicola.			
		Per cent.	Pounds per cubic foot of media.	Ratio to coal-tar creosote.	Ratio to zinc chloride.	Per cent.	Pounds per cubic foot of media.	Ratio to coal-tar creosote.	Ratio to zinc chloride.
1	Coal-tar creosote	0.55	0.343		0.91	0.225	0.140		3.0
2	Coal-tar creosote, Fraction I	.30	.187	1.8		.225	.140	1.0	
3	Coal-tar, Fraction II	.225	.140	2.5		.15	.094	1.5	
4	Coal-tar creosote, Fraction III	[2] .325	.203	1.7		.125	.078	1.8	
5	Coal-tar creosote, Fraction IV	[2] 3.3	2.059	.16		.125	.078	1.8	
6	Coal-tar creosote, Fraction V	33.0	20.59	.017		[2] 7.80	4.867	.029	
7	Water-gas-tar creosote, 1.051	3.0–4.0	1.9–2.5	.18–.14		[3]			
8	Water-gas-tar creosote, 1.012	[4] .60	[4] .375	[4] .9		[3]			
9	Water-gas-tar creosote, 1.070	[5] 40.0	+25.0	−.016		[5] 40.0	+25.0	.0056	
10	S. P. F. carbolineum	2.25	1.404	.24		[3]			
11	Avenarius carbolineum	5.25	3.27	.104		.30	.187	.75	
12	C. A. wood preserver	1.0–1.5	.6–.9	.55–.37		[3]			
13	Hardwood tar	1.25	.78	.44		.75	.468	.30	
14	Wood tar (Douglas fir)	.65	.405	.84		[2] .20	.125	1.12	
15	Beechwood creosote	.12–.24	.075–.15	4.6–2.3		[3]			
16	Spirittine	1.0–2.0	.6–1.2	.55–.27		[3]			
17	Preservol	.70	.437	.8		[3]			
18	Wood-creosote oil	[3]				[3]			
19	Timberasphalt	[5] 40.0	25.00	−.016		[3]			
20	Copperized oil	40.0	24.96	.015		[5] 40.0	+25.0	.0056	
21	Fuel oil	[5] 40.0	+25.0	−.016		[3]			
22	Kerosene	[5] 40.0	+25.0	−.016		[3]			
23	Zinc chloride	.50	.312	1.1		.75	.468	.30	
24	Zinc sulphate (commercial)	[4] .70	[4] .437	[4] .8	[4] .7				
25	Zinc sulphate (by-product)	[3]				[3]			
26	B. M. preservative	[3]				[3]			
27	Sapwood antiseptic	[5] 75.0				[3]			
28	Sodium silicate	[3]				[3]			
29	Sodium fluoride	.25	.156	2.2	2.0	.15	.94	1.5	5.0
30	Cresol calcium (see note)	.14–.28	.087–.174	3.9–2.0	3.6–1.80	[3]			

[1] Part of this table was published by C. J. Humphrey and Ruth Fleming in Jour. Ind. and Eng. Chem., February, 1914.
[2] Killing point has not been checked in duplicate. [3] Tests not completed. [4] Around. [5] Above.

NOTE.—In this table the figures have checked to within an accuracy of 10 per cent or less except those referred to by footnote 2; also in certain cases the killing point has been given as within certain limits, and further work will define these more accurately. Those toxicities indicated as "around" a certain concentration are close to the true value but may fluctuate slightly on either side; where indicated as "above" a certain concentration the result merely indicates that this is the highest concentration yet tested, and the ultimate killing point may be considerably higher. Service tests on cresol calcium have shown poor results to date.

TABLE 6.—*Corrosive action of the preservatives.*

Preservative No.	Preservative designated by cooperator as—	Loss in weight of flange steel after immersion in preservative for 4 weeks at 98° C. in ounces per square foot per week.
1	Coal-tar creosote	Less than 0.085.
2	Coal-tar creosote, Fraction I	Do.
3	Coal-tar creosote, Fraction II	Do.
4	Coal-tar creosote, Fraction III	Do.
5	Coal-tar creosote, Fraction IV	Do.
6	Coal-tar creosote, Fraction V	Do.
7	Water-gas-tar creosote, 1.051	Do.
8	Water-gas-tar creosote, 1.012	Do.
9	Water-gas-tar creosote, 1.07	Between 0.005 and 0.010.
10	S. P. F. carbolineum	Less than 0.005.
11	Avenarius carbolineum	Between 0.010 and 0.025.
12	C. A. wood preserver	Less than 0.005.
13	Hardwood tar	Between 1.900 and 2.000.
14	Wood tar (Douglas fir)	Between 1.200 and 1.300.
15	Beechwood creosote	Between 0.400 and 0.450.
16	Spirittine	Between 0.200 and 0.250.
17	Preservol	Between 1.100 and 1.200.
18	Wood creosote oil	No tests made.
19	Timberasphalt	Between 0.050 and 0.100.
20	Copperized oil	Less than 0.005.
21	Fuel oil	Do.
22	Kerosene	Do.
23	Zinc chloride, 2.4 per cent	Between 0.300 and 0.350.
24	Zinc sulphate, 4.5 per cent	Between 0.100 and 0.150.
25	Zinc sulphate (by-product), 7.2 per cent	Do.
26	B. M. preservative, 2 per cent zinc and 1 per cent alum sulphate	Between 0.700 and 0.750.
27	Sapwood antiseptic	Not tested quantitatively; copper all thrown out in a few minutes.
28	Sodium silicate	Decomposed at temperature of test.
29	Sodium fluoride, 1 per cent	Between 0.025 and 0.050.
30	Cresol calcium	Less than 0.005.

TABLE 7.—*Discoloration of wood treated with preservatives and painted.*

Preservative No.	Preservative designated by cooperator as—	Condition of painted surface after exposure for 1 month.
1	Coal-tar creosote	Very badly discolored and paint not dry.
2	Coal-tar creosote, Fraction I	Slightly yellow in spots; paint dry.
3	Coal-tar creosote, Fraction II	Very badly discolored; paint nearly dry.
4	Coal-tar creosote, Fraction III	Do.
5	Coal-tar creosote, Fraction IV	Do.
6	Coal-tar creosote, Fraction V	Very badly discolored; paint not dry.
7	Water-gas-tar creosote, 1.051	Very badly discolored, and sticky in spots.
8	Water-gas-tar creosote, 1.012	Slightly discolored; paint somewhat sticky.
9	Water-gas-tar creosote, 1.070	Very badly discolored; paint not dry.
10	S. P. F. carbolineum	Do.
11	Avenarius carbolineum	Do.
12	C. A. wood preserver	Do.
13	Hardwood tar	Do.
14	Wood tar (Douglas fir)	Do.
15	Beechwood creosote	Discolored gray; oil penetrated paint coating in several places.
16	Spirittine	Slightly discolored; paint sticky in spots.
17	Preservol	Paint discolored and collected in spots, leaving surface partly bare; still very wet.
18	Wood creosote oil	Badly discolored; paint not dry.
19	Timberasphalt	Very badly discolored; paint dry, but did not stick to wood.
20	Copperized oil	Discolored; paint somewhat sticky.
21	Fuel oil	Slightly yellow in spots; paint slightly sticky.
22	Kerosene	Slightly yellow in spots; paint dry.
23	Zinc chloride	Appearance similar to untreated specimen.
24	Zinc sulphate	Do.
25	Zinc sulphate (by-product)	Do.
26	B. M. preservative	Do.
27	Sapwood antiseptic	No test made.
28	Sodium silicate	Slightly discolored.
29	Sodium fluoride	Appearance similar to untreated specimen.
30	Cresol calcium	Discolored, pale yellow, and somewhat sticky.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1915